Reducing the Effect of Transducer Mount Induced Noise (XMIN) on Aeroacoustic Wind Tunnel Testing Data with a New Transducer Mount Design

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Overview

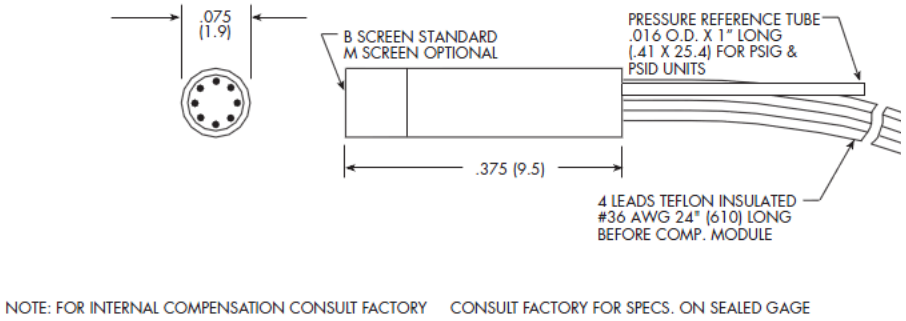
- Introduction and Motivation
- Test Proposal
- Instrumentation
- Test Operation
- Analysis
- Results

Introduction and Motivation

- **Characterization of flight vehicle unsteady aerodynamics is often studied via large scale wind tunnel testing**
  - Boundary layer noise is measured by miniature pressure transducers installed in a model

- **Noise levels (2-5 dB ref. 20 μPa) can be induced when transducer is mounted out of flush with model outer surface**

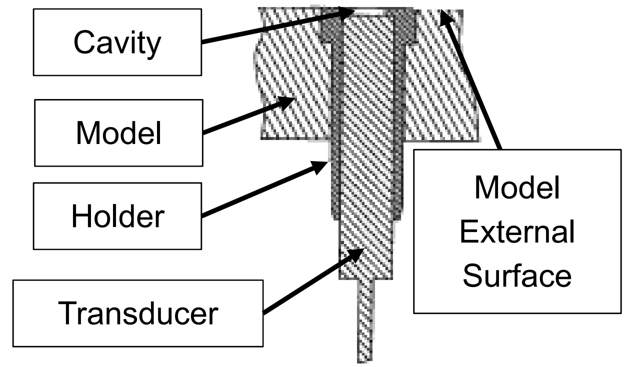
- **This effect must be minimized to accurately determine aerodynamically induced acoustic environments**

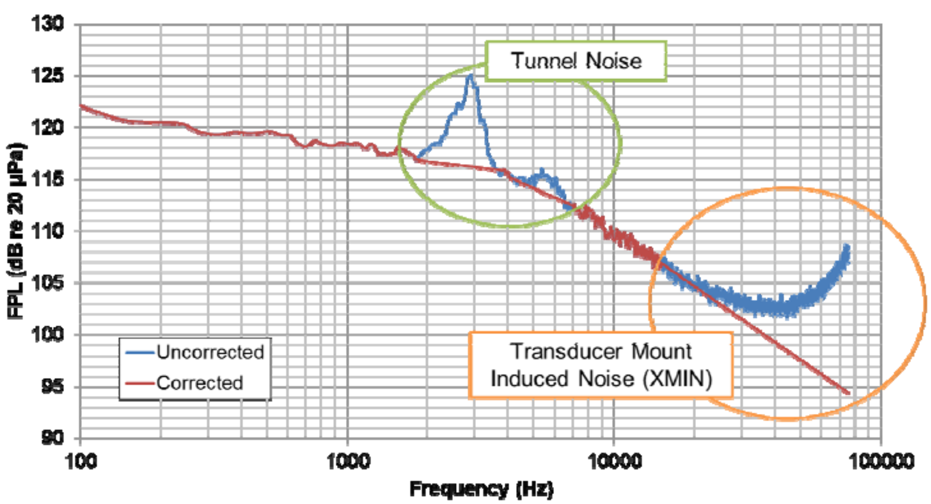


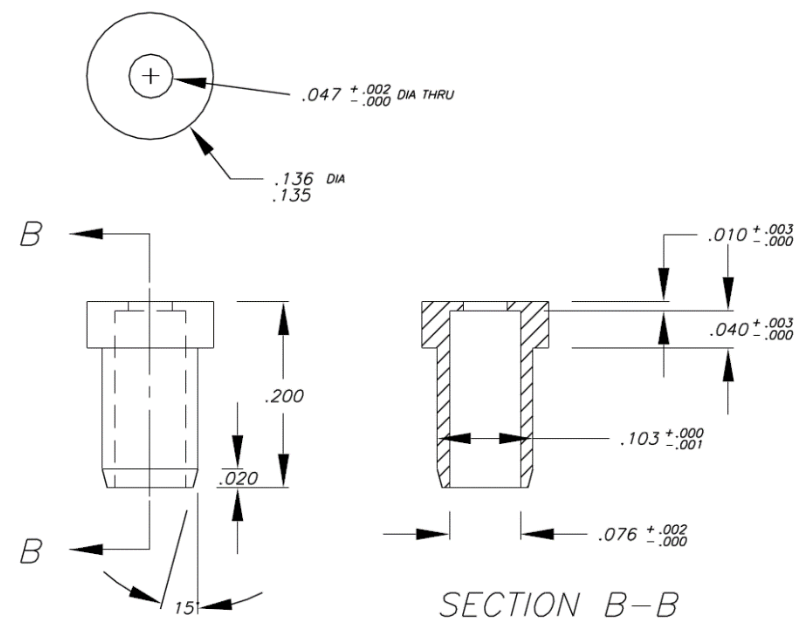
Introduction and Motivation

- **To ensure flush mounting, transducers are ordered without screen and installed in a holder with a single hole**

- **Narrowband noise is induced by the resulting cavity created by distance from model OML to transducer diaphragm**
  - This is difficult to remove from the data

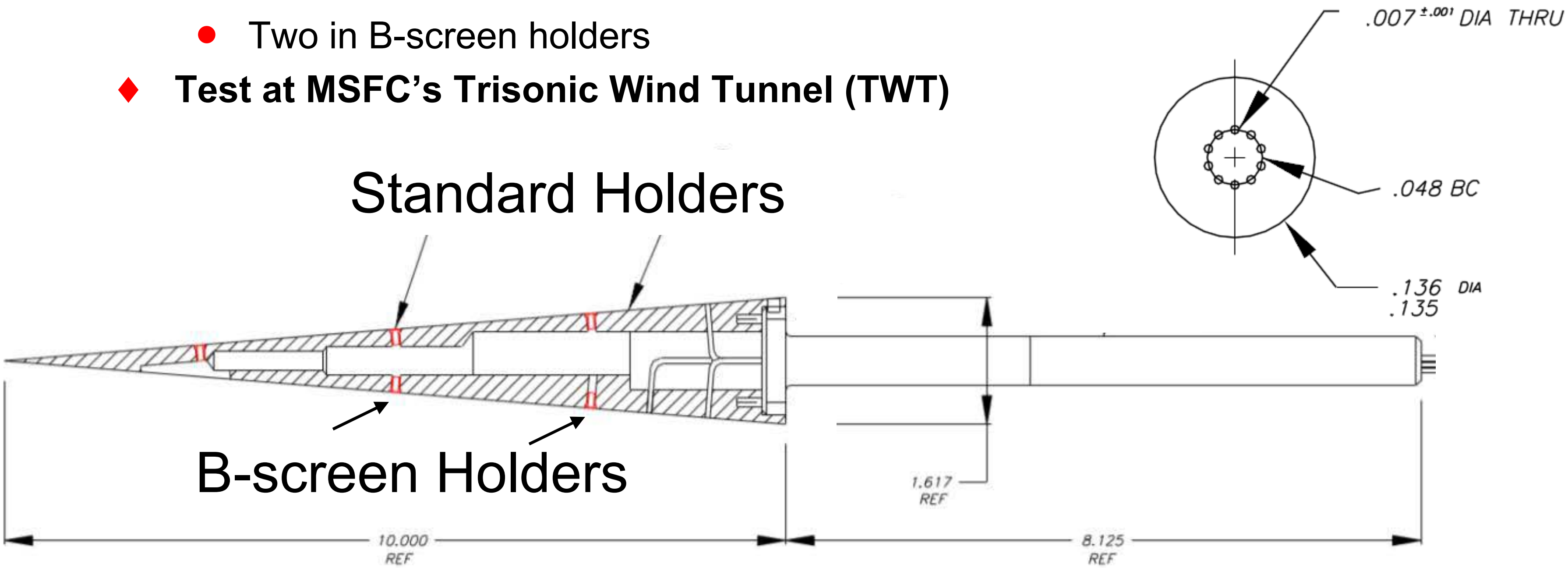






Transducer Mount Induced Noise (XMIN) Test Proposal

- **Use a holder that mimics the Kulite Semiconductors, Inc. B-screen to reduce impact of XMIN on data**
  - Replace the single hole with 10 small diameter holes in a circle
  - Either decrease XMIN amplitude or increase XMIN frequency beyond range of interest
- **Install four transducers in an acoustic calibration cone**
  - Two in standard MSFC holders
  - Two in B-screen holders
- **Test at MSFC's Trisonic Wind Tunnel (TWT)**



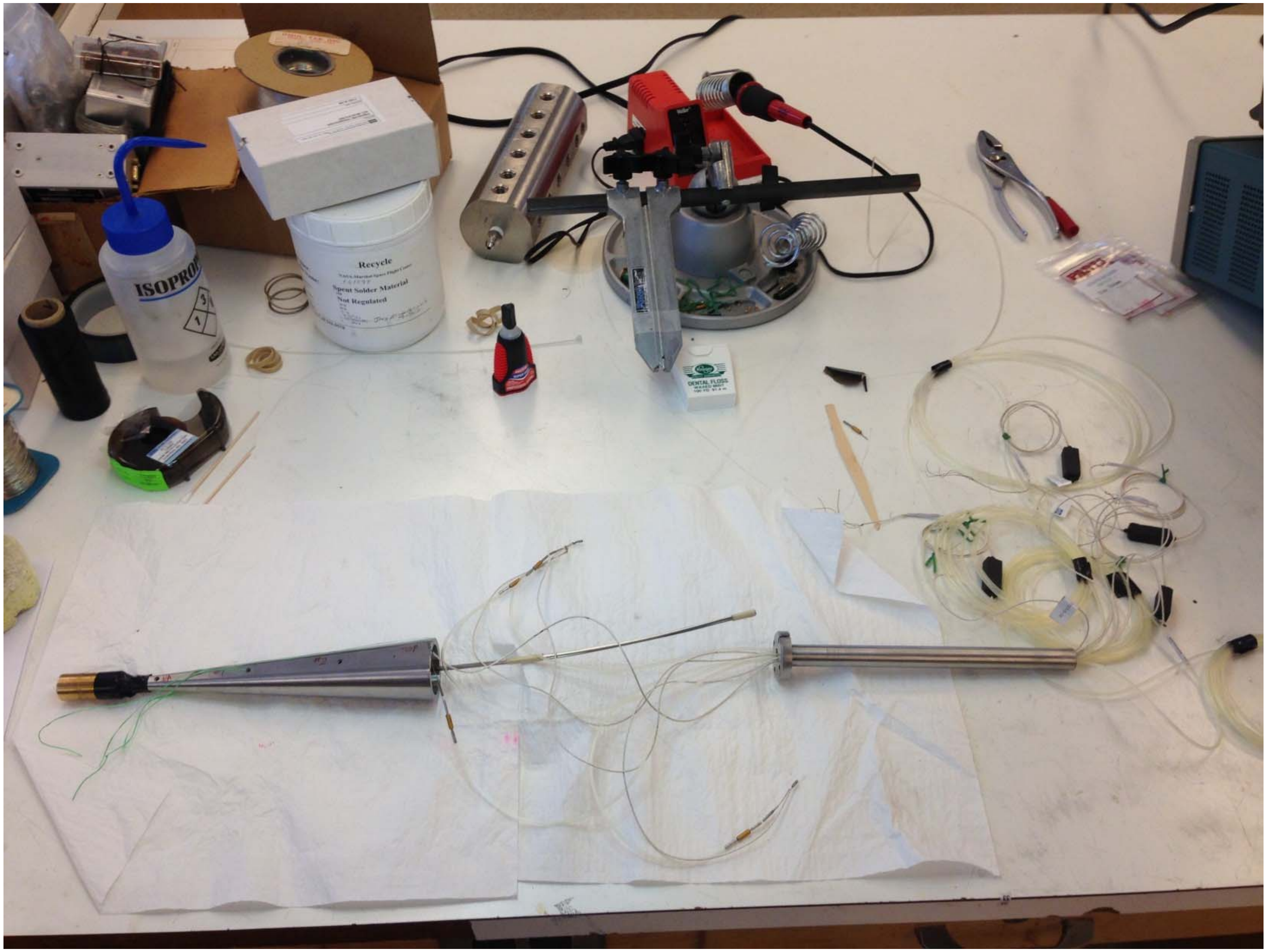
Instrumentation

- **Kulite XCL-20-IA-072-25D miniature high frequency pressure transducer**
  - NASA had used the XCL-072 series in recent unsteady aerodynamic wind tunnel test programs, lending personnel experience and familiarity
  - Transducers with modifications necessary for this test were available from previous testing providing cost savings and schedule relief

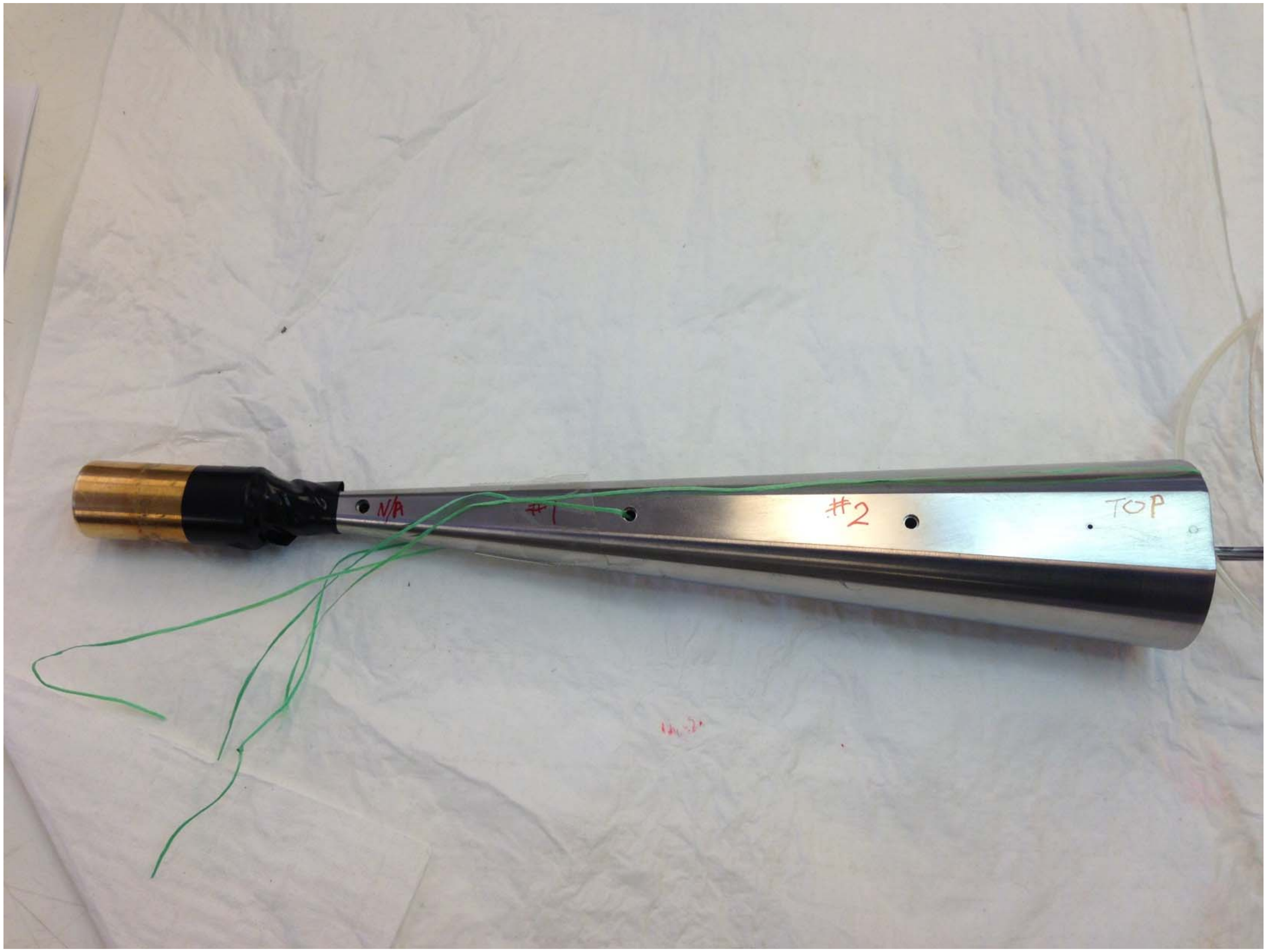
- **Transducer modifications**
  - Screens removed and diaphragm cavity backfilled with RTV for use in holders
  - Casing length reduced by 0.175" to allow installation into calibration cone
  - Recalibrated by manufacturer to 25 psid due to dynamic pressures expected in TWT
  - Integrated in-line amplifier and temperature compensation unit

- **Transducer Checkout**
  - Vacuum on transducer held for five minutes
  - Response with -5, 0, and +5 psi applied
  - Response with blast of compressed air blown across transducer

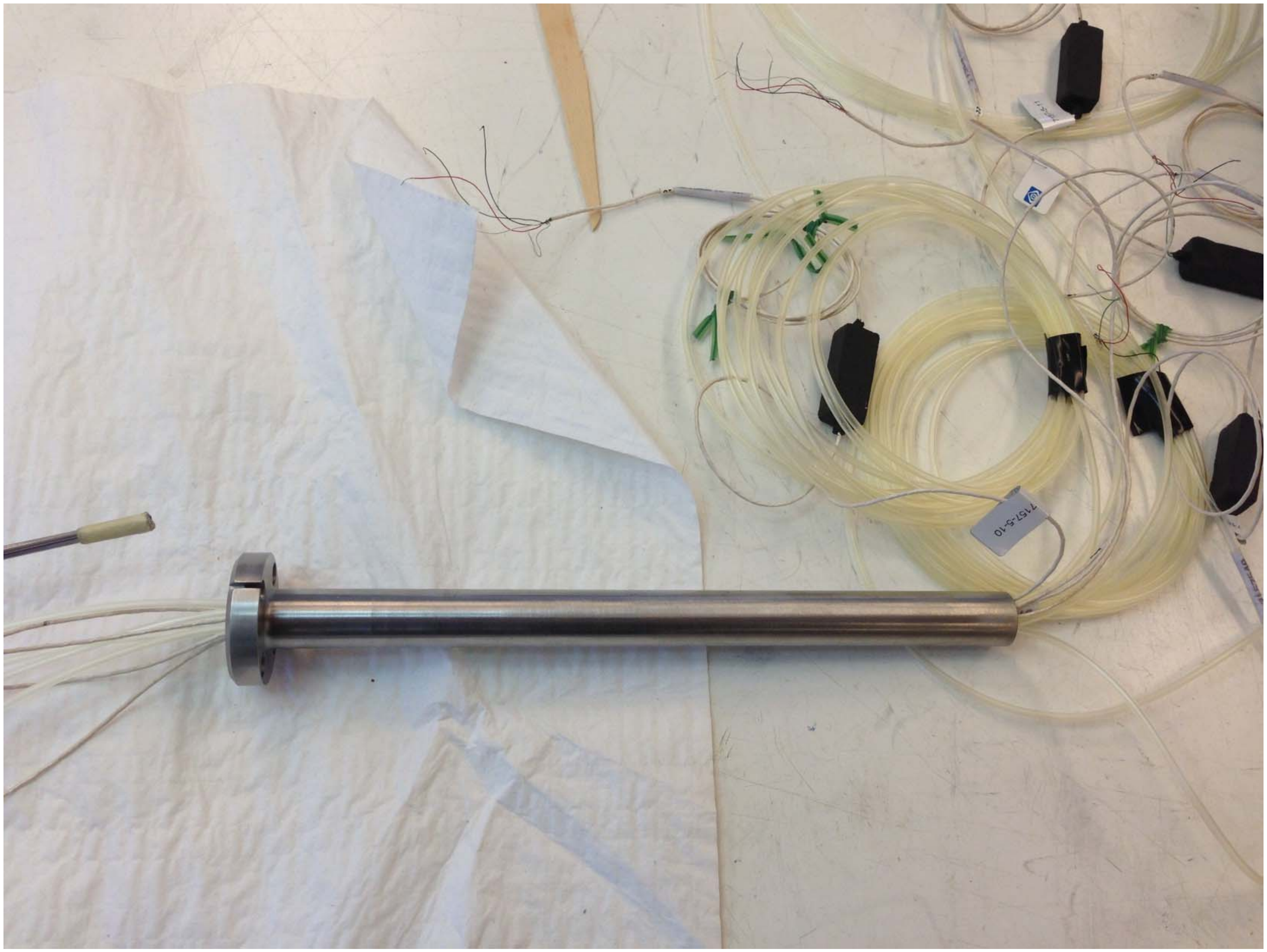
Transducer Installation



Transducer Installation



Transducer Installation



Transducer Installation

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Transducer Installation

Test Overview

- **Test Facility: MSFC 14 x 14-Inch Trisonic Wind Tunnel**
- **Facility Test Number: XP1.7**
- **Mach Range: 0.80 – 1.96**
- **Angle of Attack: α = 0°, ±1°, ±2°, ±4°, ±8°**
- **Model Roll: φ = 0°, 90°, 180°**
- **Number of Runs: 83 (273 test conditions)**
- **Run Type: Pitch-Pause**
- **Dwell Times Per Condition:**
  - ~60 sec for α = 0° runs
  - ~5 sec for α-sweep runs
- **Test Length: 3 days (Feb 11-13, 2013)**

- **High Speed Data Acquisition: Agilent System**
  - Eight-channel board
    - 4 transducers, 1 angle of attack, 3 empty
  - Sample Rate: ~196 ksps
  - AC coupled
  - Manufacturer provided transducer calibration data used

- **Success Criteria Met**
  - Useful data collected over a broad range of transonic Mach numbers

Test Matrix (As Run)

Config	Trip	Alpha	Roll	Mach 0.80	0.90	0.95	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.46	1.69	1.96	#runs
XMIN1	N	A0	0	10	11	12	18	17	16	15	14	19	13				10
	N	A0	0	85	86	87	89	90	91	93	92	94	88				10
	N	A1	0				21					20					2
	N	A2	0	29	30	31	24	25	26	27	28	33	32				10
	N	A1	90	38	37	36	39	40	41	42	43	34	35				10
	N	A1	180	49	50	51	48	47	46	45	44	53	52				10
	Y	A0	0	56, 57, 58								54					4
	Y	A2	0									55					1
	Y	A3	0	59	60	61	67	68	69	70	71	72	62				10
	Y	A4	0	63	64	65							66				4
	Y	A1	90	x	x	x	x	x	x	x	x	x	x				0
	Y	A1	180	x	x	x	x	x	x	x	x	x	x				0
	N	A0	0											83	81	79	3
	N	A3	0											84	82	80	3
	N	A1	90											x	x	x	0
	N	A1	180											x	x	x	0
	Y	A0	0											74	75	77	3
	Y	A3	0											73	76	78	3
	Y	A1	90											x	x	x	0
	Y	A1	180											x	x	x	0
																	83

Sector Schedule:

A0	ALPI= 0, 0, 0, 0, 0
A1	ALPI= -2, -1, 0, +1, +2
A2	ALPI= -4, 0, +4
A3	ALPI= -4, -2, 0, +2, +4
A4	ALPI= -8, -4, 0, +4, +8

Missing Runs:

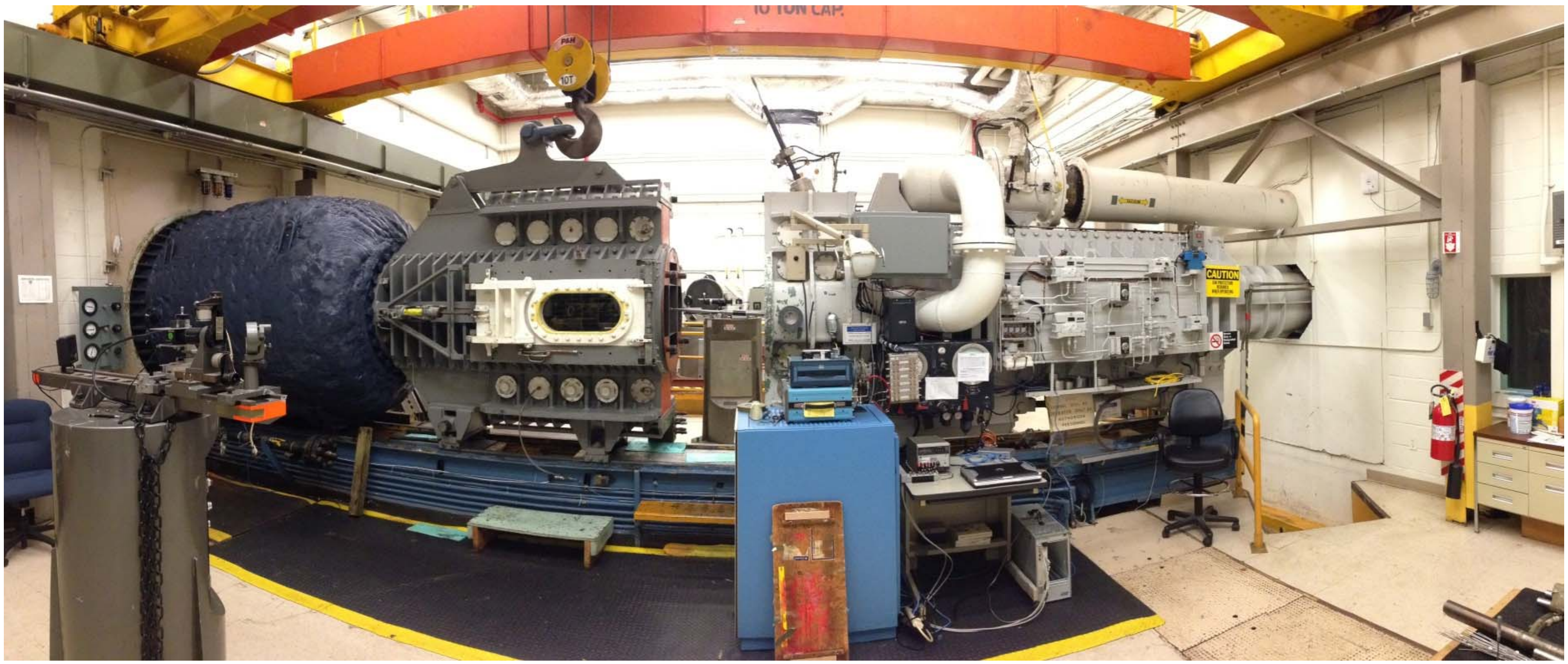
1-9, 22	checkout
23	abort

Trip Information:

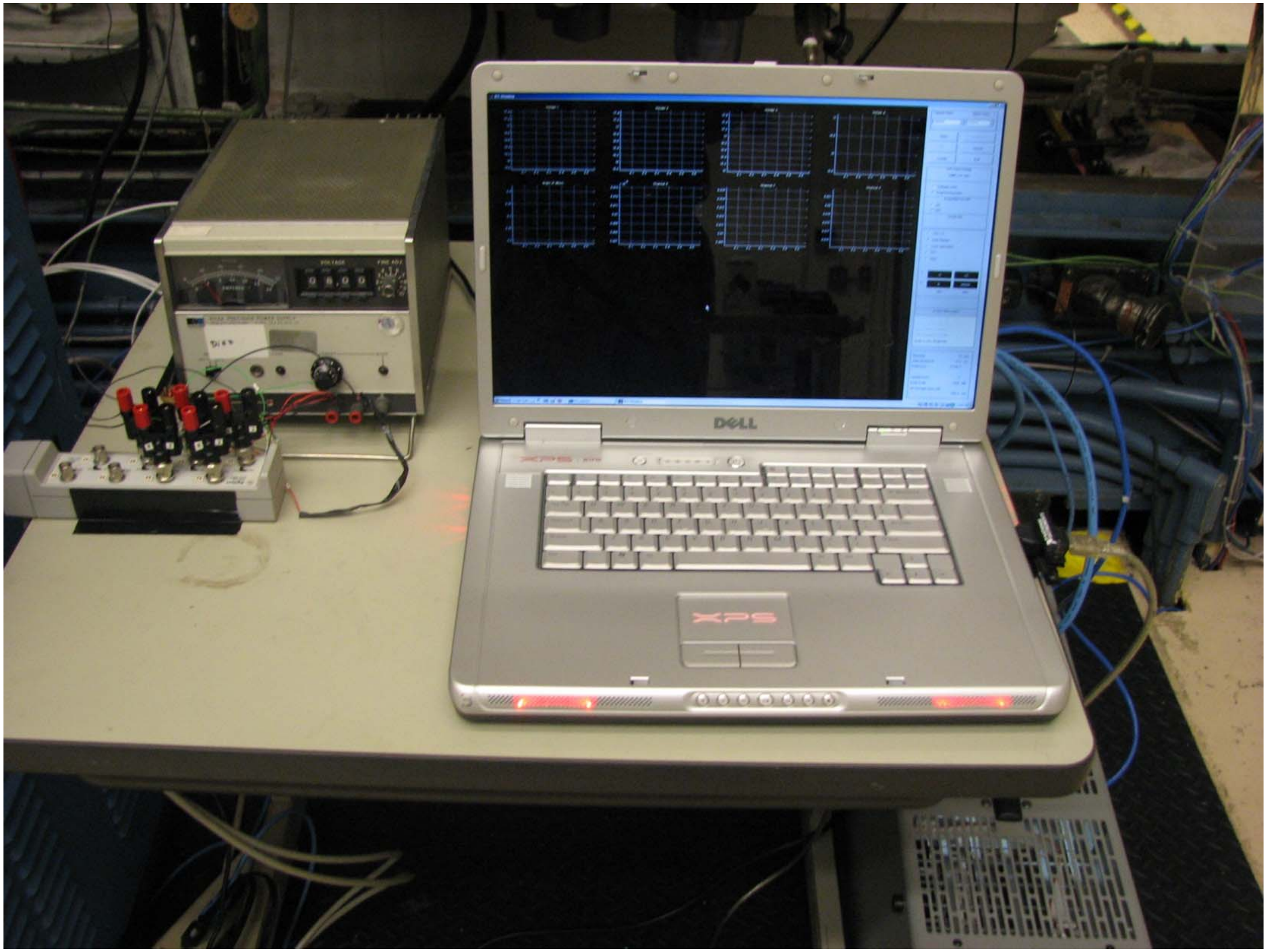
54-56	0.090 in. hightape layers placed midway between kulite holders 1/3 and 2/4
57	solder circle with tape layers placed just upstream of kulite holders 2/4
58-78	0.120 in. high aluminum ring placed just upstream of kulite holders 2/4

x — run designated in the original matrix, but later deleted as being not required based on test results

Tunnel Installation and Setup



Tunnel Installation and Setup



Tunnel Installation and Setup

Analysis

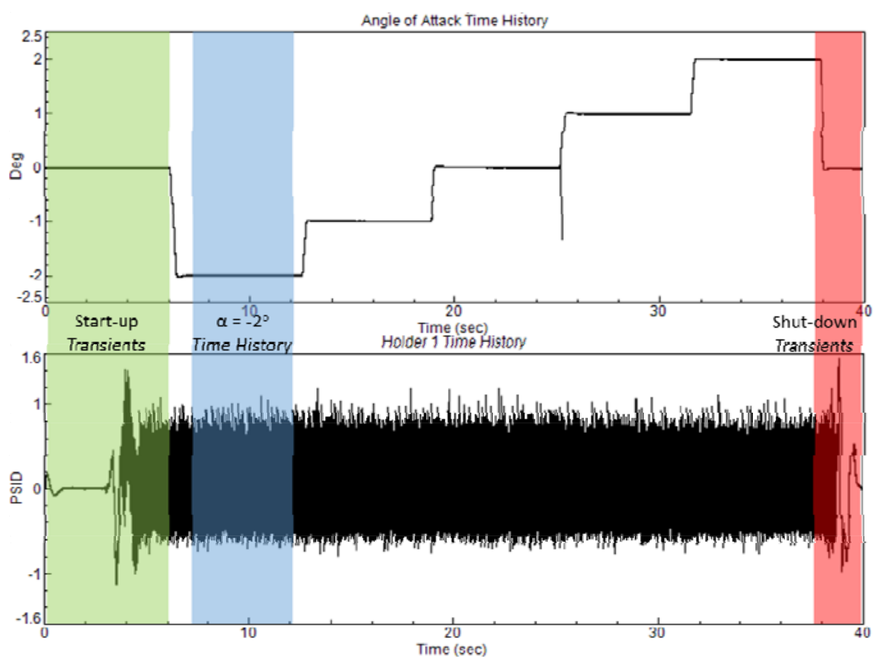
- **FFT data reduction using AI Signal Research Inc. PC Signal© signal analysis software**

- **Comparisons made in both power spectral density (PSD) and 1/3 octave fluctuating pressure level (FPL)**
  - All data were examined in model scale

- **Sample rate achieved: 196,608 sps**

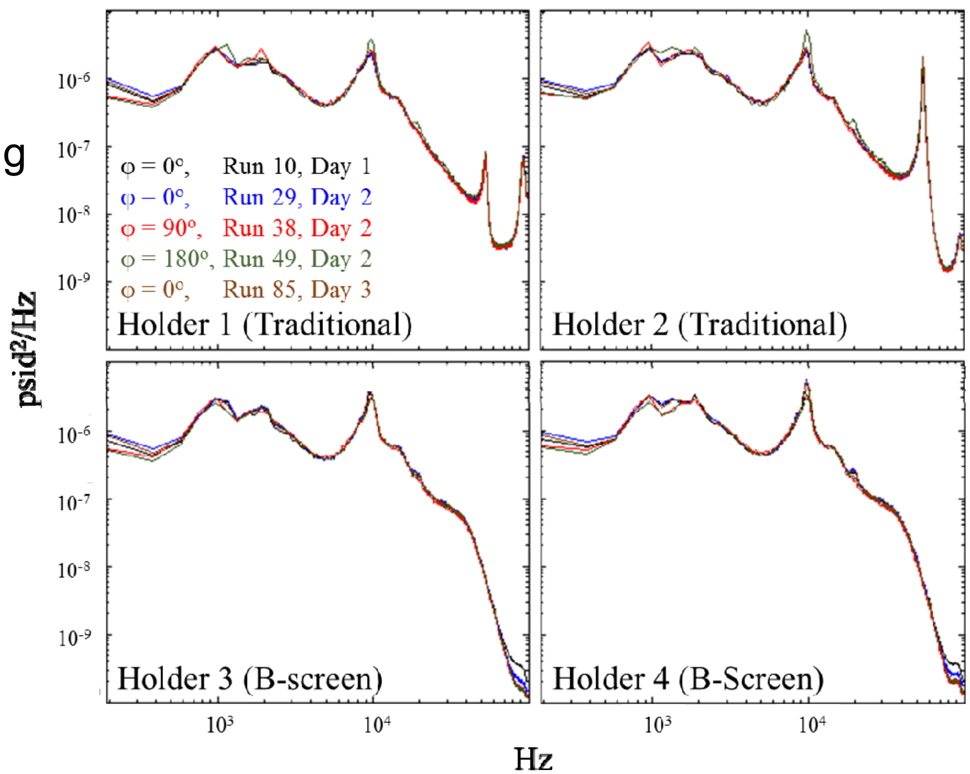
- **Nyquist cutoff = 2**

- **High frequency data mapped to static tunnel data via run number and angle of attack data recorded by high frequency system**



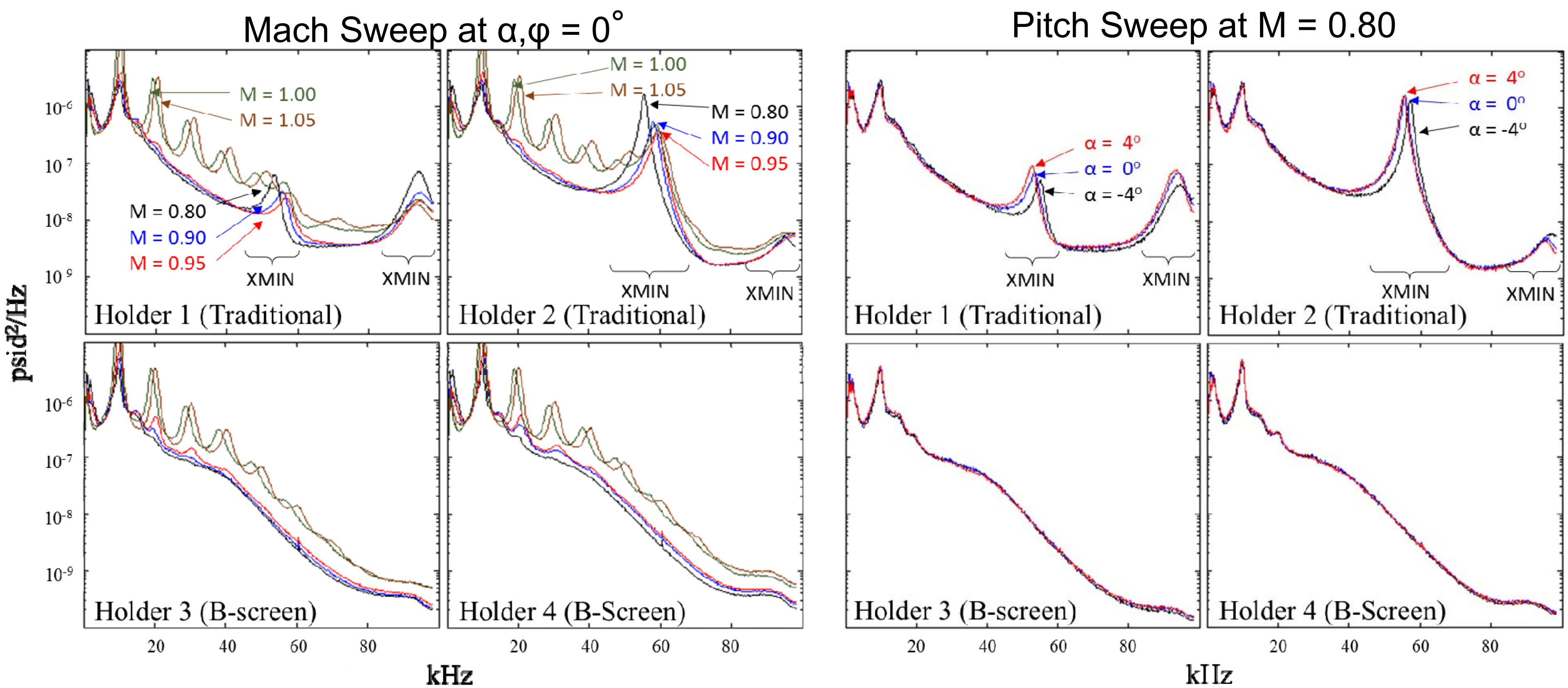
Data Quality

- **Repeatability**
  - Repeat runs at α,φ = 0° conducted throughout each day of testing for M = 0.8 – 1.30
  - Runs at φ = 90°, 180° to rule out tunnel wall bias
- **Transducer Health**
  - Initial checkouts
  - Air-off runs each day of testing
- **Time History Checks**
  - Indicate correct order of magnitude
  - Show no signs of clipping or sensor over-ranging
  - Histograms show data to be Gaussian distributions with minimal skewness



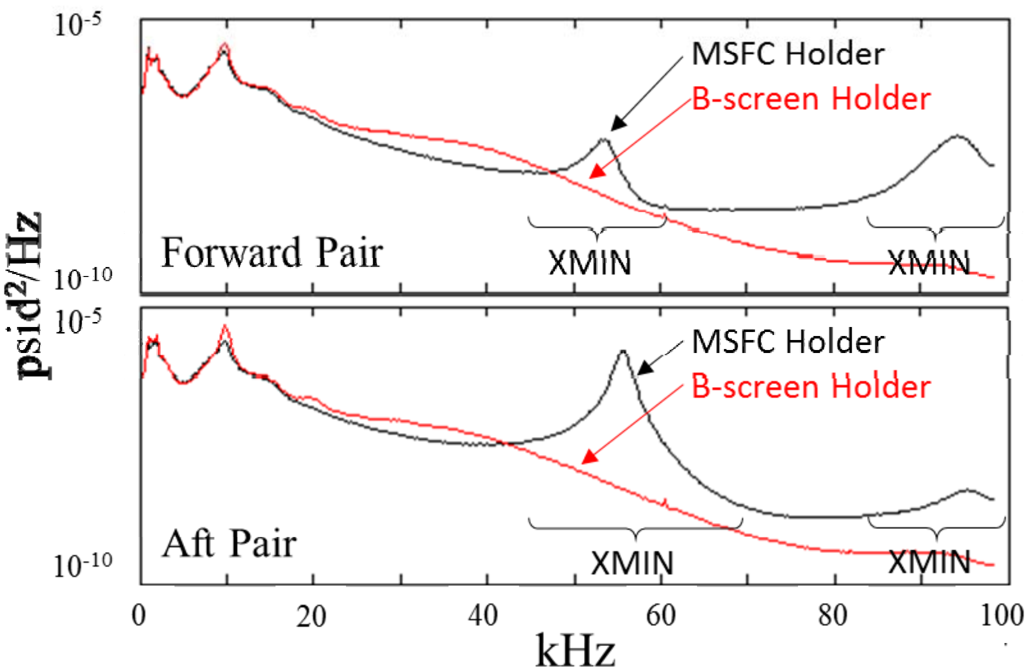
Results

- **Flow characteristics are as expected for facility, model, and holders**
  - Tunnel noise is dominant, especially above M = 0.95 (1 kHz and 10 kHz)
  - M = 0.80, 0.90, and 0.95 are most useful for this experiment
  - XMIN is seen at ~55 kHz in traditional holders and not in B-screen holders



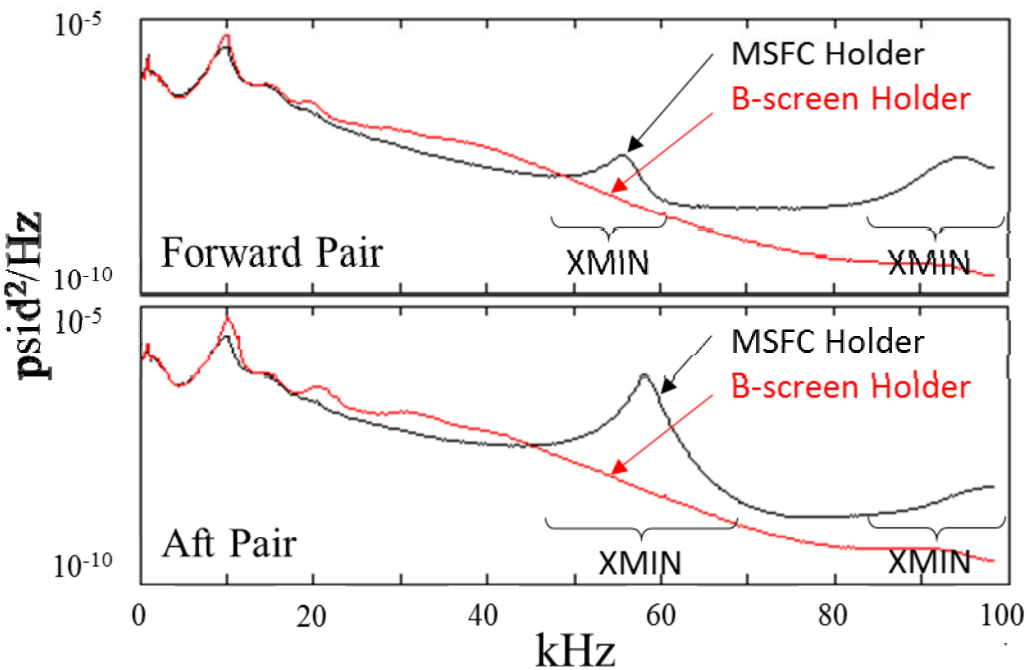
Results

- M = 0.80



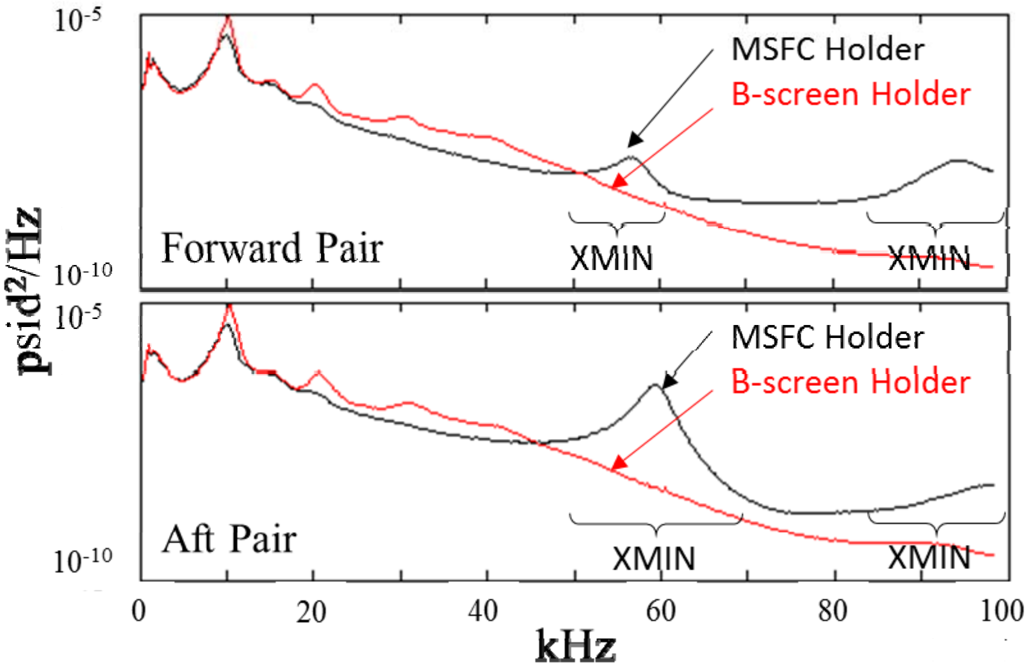
Results

- M = 0.90



Results

- M = 0.95



Conclusions

- **Test success criteria met**
  - Useful data collected over a broad range of transonic Mach numbers

- **Data show that the B-screen holder is effective at minimizing XMIN without reducing externally driven noise**

- **Sufficient evidence provided to motivate the use of the B-screen holder for large scale aeroacoustic wind tunnel testing with minimal risk to data collection**
  - Utilized for SLS Ascent Aeroacoustic Test (~350 transducers) and resulting data showed minimal evidence of XMIN